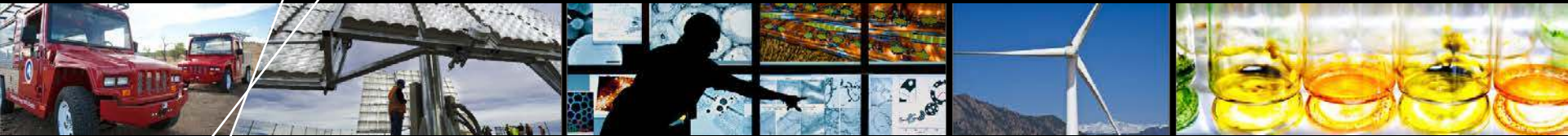# The Wind Integration National Dataset (WIND) toolkit

EWEA Wind Power Forecasting Workshop, Rotterdam
December 3, 2013

Caroline Draxl

NREL/PR-5000-60977

Impact of high wind penetrations on power systems operations?

Photo by Jamie Keller, NREL 19697

Photo by Energy Northwest, NREL 12307

Impact of high wind penetrations on power systems operations?
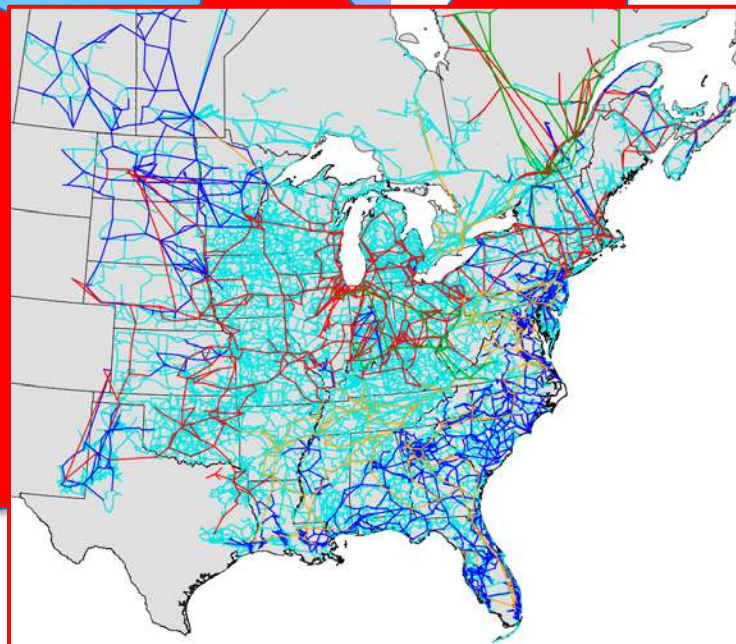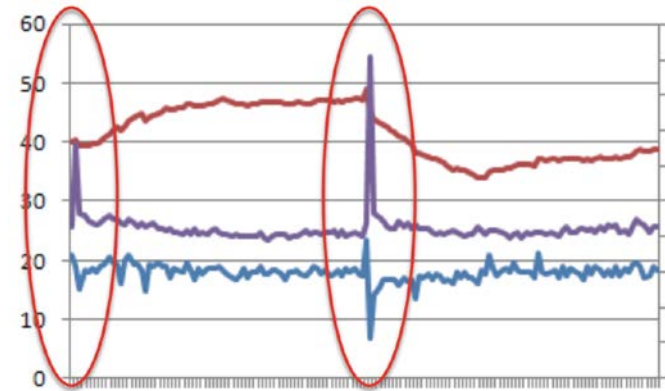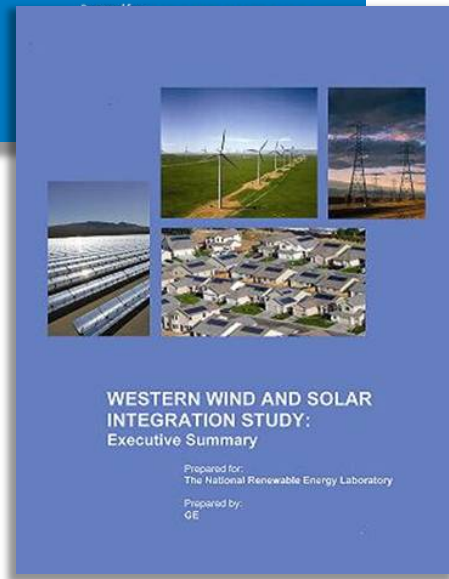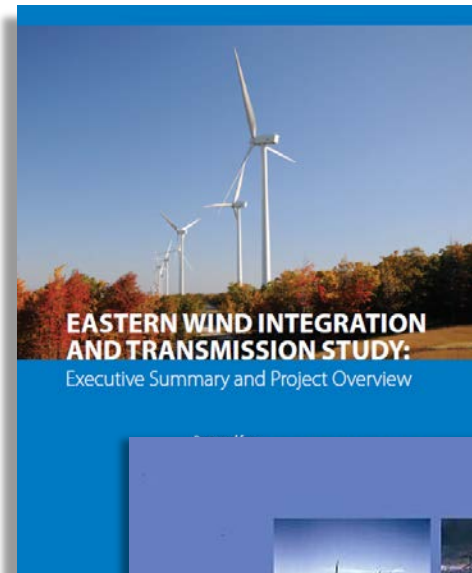

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Photo by Energy Northwest, NREL 12307

Need for high resolution wind power data

Artifacts still remain after corrections
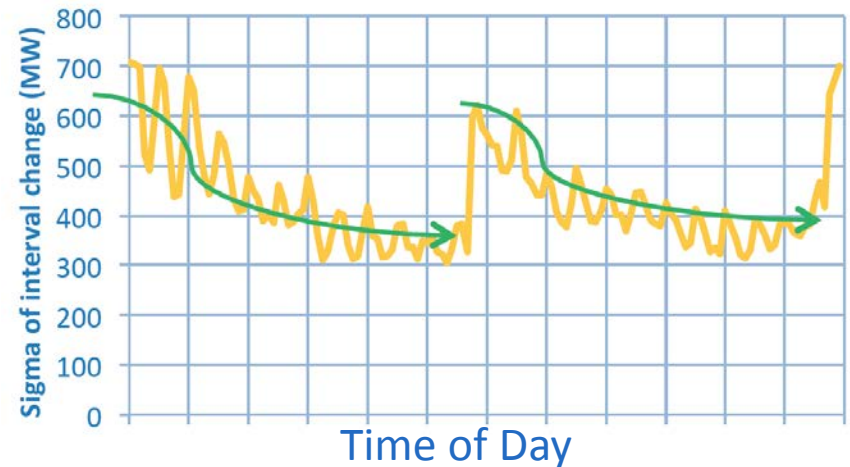
Need for high resolution wind power data

- **Realistically reflects ramp characteristics**
- **Spatial seams**
- **Capacity factors of wind plant production**
- **Time-synchronous with load profiles**
- **Recent years**
- **Lasts at least 4 years to evaluate inter-annual variability**
- **Easy access.**

Wind power forecasts and production time series for 2007–2013

Wind Integration National Dataset WIND toolkit:

|	
Re-analysis: Meteorological and power data set	Re-forecast: power data set (1 h, 4 h, 6 h, 24 h)

Freely available online data extraction tool

Acknowledgements:

- NREL: Bri-Mathias Hodge, Dan Getman, Wesley Jones, Kirsten Orwig
- 3 TIER: Jim McCaa, Padriac Fowler, Eric Grimit
- Members of Technical Review Committee
- U.S. Department of Energy.

# The Weather Research and Forecasting (WRF) model setup
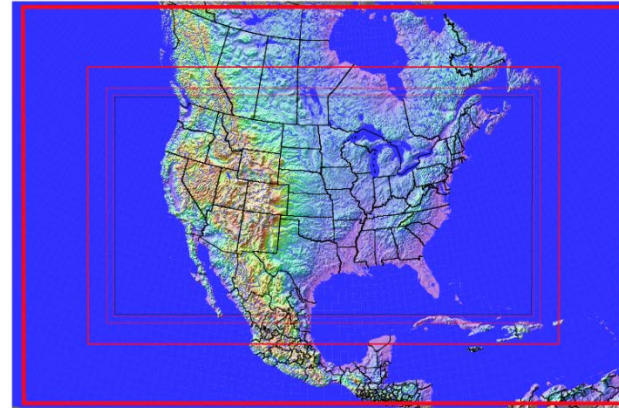
- **WRF V.3.4.1**
- **2 km for re-analysis, 6 km nest for forecasts**
- **Boundary conditions: NOAA Reforecast2 Global Ensemble Forecast System Control 1-degree, NCEP Real-time global 1/12ᵗʰ degree Sea Surface Temperature analysis**
- **Model output: 5 min for re-analysis, 1 h for forecasts**
- **Terrain U.S. Geological Survey GTOPO30**
- **Yonsei University (YSU) boundary layer scheme, topographic wind enhancement**
- **100+ terabytes model output: Parallel asynchronous I/O to improve output speed 50:1.**

126,000 land-based and offshore existing and potential wind facilities

- **Each site is a 2x2-km grid cell in the numerical weather prediction data set**

- **Site selection process**
  - Exclusion criteria:
    - Federal lands, national parks, open water areas
    - Areas with slopes greater than 20%
    - Within buffer area of developed land and airports
    - Offshore: wind resource, distance from shore at least 8 km, bathymetry (max depth 30 m)

- **Ranking based on computed potential MWh.**

126,000 land-based and offshore existing and potential wind facilities
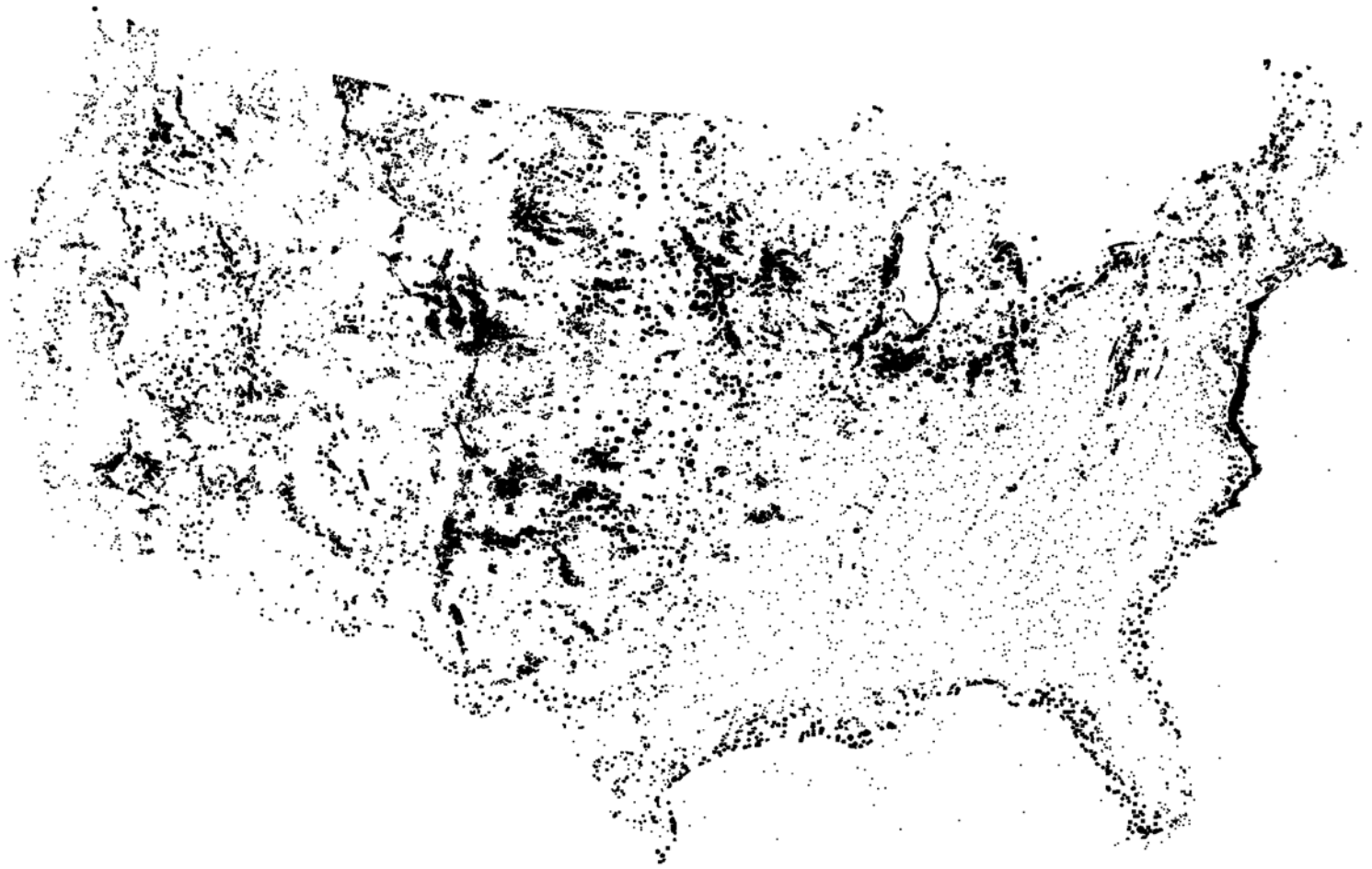
Create state-of-the-art forecasts without "cheating"

by mimicking "real" forecast errors

Create state-of-the-art forecasts without "cheating"

by mimicking "real" forecast errors

- **NWP is the basis**
  - Initialized daily at 00 UTC
  - 6-km grid
  - Hourly output.
- **Respect the spatial-temporal correlation of typical forecast errors at forecast horizons**
- **For forecast horizons <= 6 h: statistical model for each site**
- **Post processing at each site to remove bias**
- **Each forecast: deterministic value + P10/P90 probability of exceedance values.**

Probabilistic forecasts with nonparametric error quantiles

- **Empirical forecast error distributions differ based on power regime**

- **Conditional, nonparametric dressing approach**

- **Yields approximate calibration (reliability)**

- **Dynamic adjustment to weather regime changes and seasonal forecast skill.**
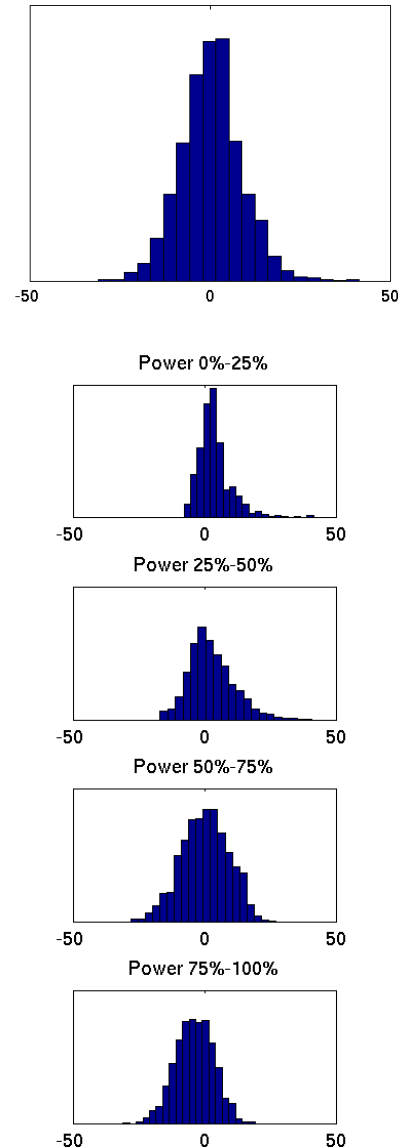
Power 0%-25%

Power 25%-50%

Power 50%-75%

Power 75%-100%

Power conversion

- **Bias removal from wind speeds:**
  - Time series smoothing
  - Blend in "truth" with a limited weight
  - Adjust until forecast time series and error histograms are reasonable and error metrics are similar to state of the art.
- **Wind speed adjustment for wakes:**
  - Max. two turbines per square kilometer, each site max. eight 2-MW turbines
  - Apply wake losses to wind speed
  - Each 2x2-km site considered independently.
- **Application of power curves**
- **Statistical adjustment to power using total variance, autocorrelation of sites, spatial covariance.**
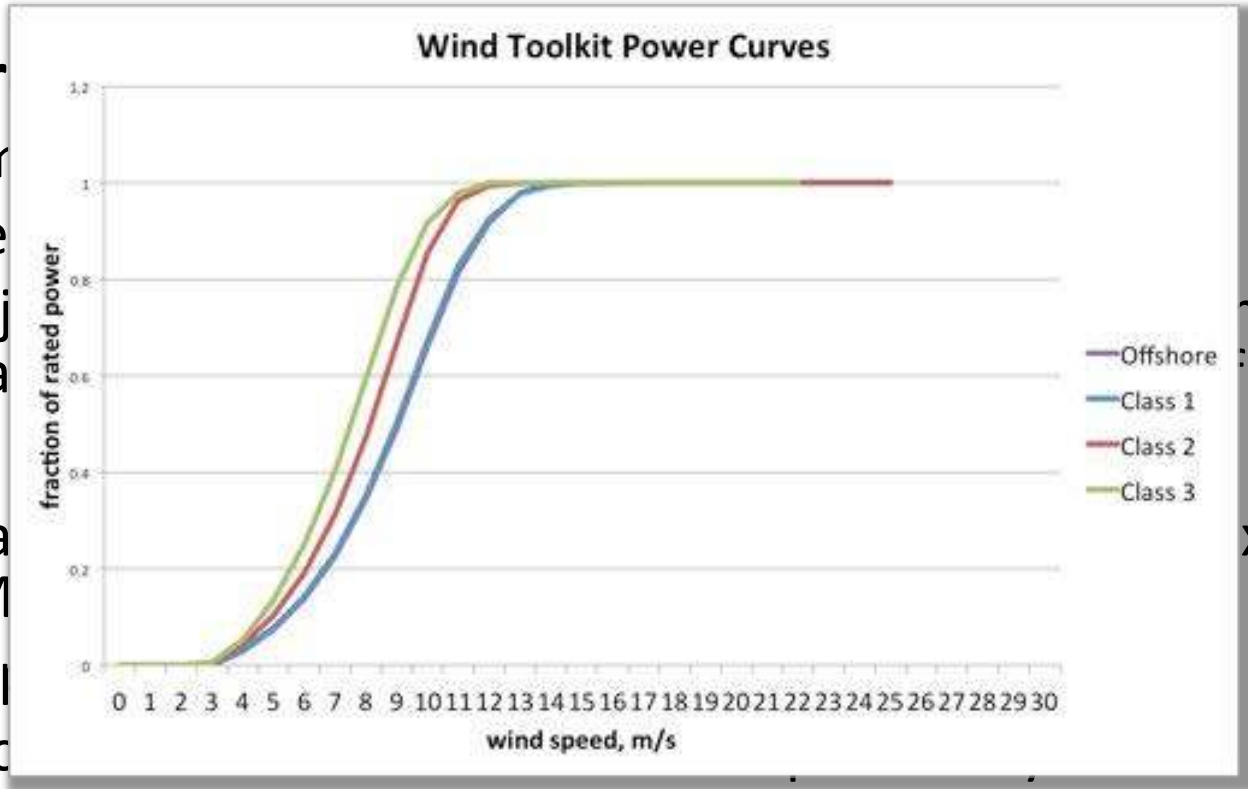
Power conversion

- **Bias r**
  - Tim
  - Ble
  - Adj   ms are
    rea   the art.
- **Wind**
  - Ma   x. eight
    2M
  - App
  - Eac
- **Application of power curves**
- **Statistical adjustment to power using total variance, autocorrelation of sites, spatial covariance.**

Wind Toolkit Power Curves

- Offshore
- Class 1
- Class 2
- Class 3

y-axis: fraction of rated power

x-axis: wind speed, m/s

Power conversion

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Online data extraction tool

developer.nrel.gov

Summary

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Deterministic and probabilistic power forecasts: mimicking current industry forecast errors

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Caroline.Draxl@nrel.gov
Bri-Mathias.Hodge@nrel.gov